Photoemission spectromicroscopy studies on epitaxial lateral overgrowth GaN surfaces

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INTRODUCTION

Gallium nitride (GaN) materials are very useful for fabricating electronic and electro-optic devices, such as high power electronics, blue and ultraviolet light emitting diodes (LED), detectors, and laser devices.[1,2,3] However, the development of III-V nitride materials and devices has suffered from the lack of the availability of low-dislocation-density, lattice-matched substrates for device synthesis. Recently, epitaxial lateral overgrowth (ELO) technique[4] produces GaN with a remarkable reduction of the dislocation density to about 10^4 per cm^2 or less. This method starts with a layer of GaN on sapphire (or SiC) which is then patterned with SiO_2 stripes of about 15 μm wide separated by 3 μm windows. The final MOVPE growth starts in the windows growing up and over the SiO_2 stripes because the film will not "seed" on it. Between two adjacent final stripes is where the growth fronts meet and coalesce. It is above the middle of the SiO_2 stripes.

EXPERIMENTS

In this work, synchrotron-radiation-based photoemission spectromicroscopy was performed to investigate the inhomogeneities in the electronic structures of the ELO GaN surfaces. MAXIMUM microscope[5] on beamline 12 at ALS is used for the studies, which operated at phone energy of 130 eV. The phone energy is quite appropriate for semiconductor investigations. Data are collected in two modes: (a) the scanning mode where a 2-D image is acquired by measuring the photoelectrons in a given kinetic energy window, and (b) the microprobe mode where an energy distribution curve (EDC) is acquired at the position of interest. The spot size has been measured to be 0.1 μm. A cylindrical mirror analyzer (CMA) is used to detect the energy-resolved emission.

RESULTS

The AFM image of the ELO GaN surface (sample M287) is depicted in the 100X100 μm^2 image of Fig. 1(a). The line scan along the horizontal line across the image is shown in Fig. 1(b). The scanning-mode measurement of the photoemission signal with the spectromicroscope is used to obtain an overview. Figure 2(a) is the image and (b) is the line profile. The 100X100 μm^2 image is acquired with a step size of 1 μm by recording the signal from Ga 3d core-level emission peak at a kinetic energy of 104.6 eV. In the image, bright areas correspond to stripes of GaN and dark areas are stripes due to the meeting-fronts grooves. The photoemission signal (PESS) line profile shows the same general features as the AFM data shown in Fig. 1. The PESS signal has a bit wider

"V" groove than the AFM micrograph, about 4.2 and 3.6 μm, respectively. The contrast mechanism producing the spectromicroscopy image is largely due to the angular dependence of the photoemission yield combined with different orientations of plateau areas and the valley areas.

For better understanding of inhomogeneities of the sample's surface electronic structure, high-spatial-resolution images are acquired. Then, based on this image, localized EDC's of the Ga 3d core level emission are obtained by the microprobe mode from different locations on the surface. Figure 3(a) shows a 30X30 μm^2 image with a step size of 0.3 μm made with the Ga 3d peak emission at an electron kinetic energy of 104.6 eV. Panel (b) is the line profile across the sample surface at the arrow-marked position on the image. Localized EDC's for the Ga 3d core level are obtained from the sample at positions labeled a, b, and c on the image which are located at the meeting-fronts area; lateral overgrowth area; and vertical-growth window area, respectively. The spectra are shown in Fig. 3(c) where the three EDC's are normalized to the same peak intensity. The difference curve "c-b" is a flat featureless line, which demonstrates the uniformity in surface electronic structures for the vertical growth window areas and the lateral overgrowth areas. However, curve a, which is from a meeting-fronts area shows an energy shift of 0.15 eV. The difference curve "b-a" is also flat after curve a and b are lined up. The observations suggest no line shape changes. The observed peak shift is attributed to a change in the surface-Fermi-level position for the crystal orientation of the growth fronts compared to (0001) orientation of the flat areas. The observed uniformity of the line shape suggests the chemical environment of Ga is the same in the different regions.

ACKNOWLEDGMENTS

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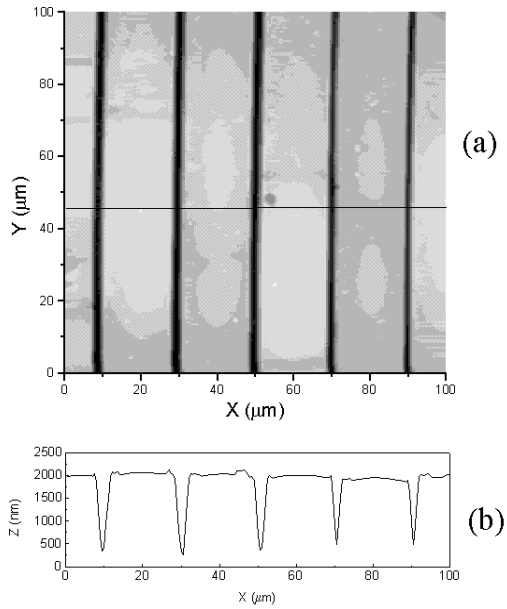


Figure 1 (a) An AFM image for a 100X100 μm^2 area of the ELO GaN surface (sample M287). The bright areas represent the flat growth stripes and the dark areas are the meeting fronts of the growth stripes. (b) A line profile obtained from the above image at the position marked by the horizontal line across the image.

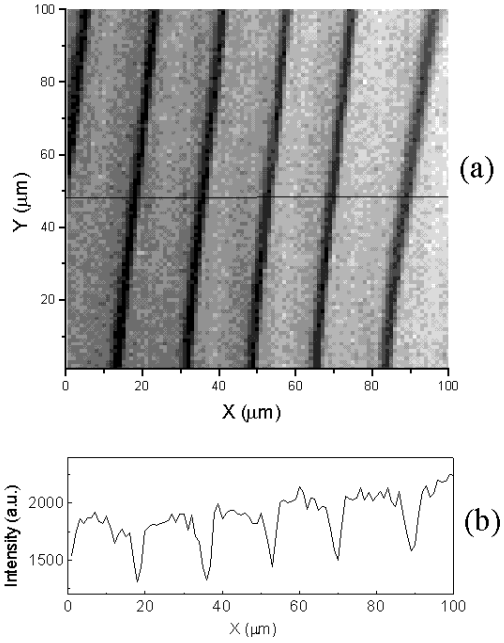
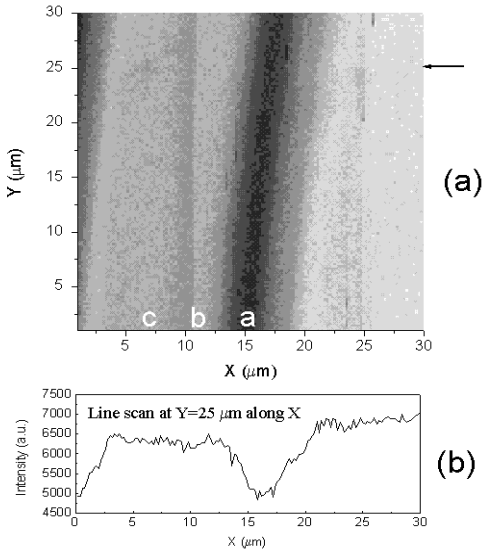


Figure 2 (a) A photoemission spectromicroscopy image for a 100X100 μm^2 area of the ELO GaN surface (sample M287) formed by the signal at the peak of the Ga 3d core - level emission at a kinetic energy of 104.6 eV. The bright areas represent growth stripes and the dark areas represent the stripes where the growth fronts meet. The CMA detects the electron emission directed to the left. (b) A line profile obtained at the position of the line on the image.



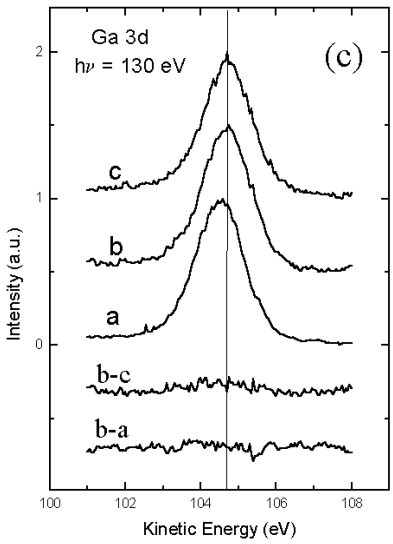


Figure 3 (a) A photoemission spectromicroscopy image for a 30X30 μm^2 area of the ELO GaN surface (sample M287) formed by the signal at the peak position of the Ga 3d core level emission at a kinetic energy of 104.6 eV. (b) A line profile obtained at the position marked by the arrow. (c) Ga 3d core level EDC's collected with 0.1 μm beam spot at the positions a, b and c shown on the image. The curve "b-c" is the difference between curve b and c, where one is from the vertical growth in the window and the other is from the lateral overgrowth area, respectively. The "b-a" is the difference between curve b and curve a, which is from a meeting-fronts region after they are shifted by 0.15 eV to line up the peaks.